

1. An electrical power generator for use in conjunction with a subterranean well, the generator comprising:

a fluid conduit configured for flow of fluid therethrough; and

5 a piezoelectric material attached to the conduit, the piezoelectric material producing electricity in response to pressure fluctuations in the conduit.

2. The generator according to Claim 1, wherein the pressure fluctuations are due to fluid flowing through the conduit.

3. The generator according to Claim 1, wherein the fluid conduit is generally tubular.

4. The generator according to Claim 3, wherein the conduit is connectable in a tubular string positioned in the subterranean well.

15 5. The generator according to Claim 1, wherein the fluid conduit includes a reduced thickness portion thereof, the piezoelectric material being attached proximate the reduced thickness portion.

6. The generator according to Claim 5, wherein the reduced thickness portion has an increased degree of flexing in response to the pressure fluctuations in the conduit than does the remainder of the conduit.

20 7. The generator according to Claim 1, wherein the piezoelectric material is attached to an external surface of the fluid conduit.

8. The generator according to Claim 1, wherein the fluid conduit is shaped so that it induces turbulence in fluid flow therethrough.

9. The generator according to Claim 1, wherein the fluid conduit is helically shaped.

5 10. The generator according to Claim 1, wherein the fluid conduit has a recess internally formed thereon, the recess inducing turbulence in fluid flow through the fluid conduit.

11. The generator according to Claim 10, wherein the recess extends generally helically on the fluid conduit.

10 12. The generator according to Claim 1, wherein the conduit is made of a titanium material.

13. The generator according to Claim 1, wherein the conduit is made of a composite material.

14. A method of producing power in a subterranean well, the method comprising the steps of:

attaching a piezoelectric material to a fluid conduit;

interconnecting the fluid conduit in a tubular string;

5 positioning the tubular string in the well; and

flowing fluid through the fluid conduit, the piezoelectric material producing electricity in response to the flowing of fluid through the conduit.

15. The method according to Claim 14, wherein the attaching step further comprises attaching the piezoelectric material externally to the fluid conduit.

16. The method according to Claim 14, wherein the attaching step further comprises attaching the piezoelectric material to a reduced thickness portion of the fluid conduit.

15 17. The method according to Claim 16, wherein in the flowing fluid step, the reduced thickness portion flexes in response to the fluid flowing through the conduit greater than that of the remainder of the fluid conduit.

18. The method according to Claim 14, wherein the flowing step further comprises inducing turbulence in the fluid flowing through the fluid conduit.

19. The method according to Claim 18, wherein the inducing turbulence step further comprises shaping the fluid conduit in a manner increasing turbulence in the 20 fluid flowing through the fluid conduit.

20. The method according to Claim 19, wherein the shaping step further comprises helically forming the fluid conduit.

21. The method according to Claim 19, wherein the shaping step further comprises forming a recess internally on the fluid conduit.

5 22. The method according to Claim 21, wherein the forming step further comprises forming the recess helically on the fluid conduit.

USPTO-2023-0622-00000000000000000000000000000000

23. An electrical power generator for use in conjunction with a subterranean well, the generator comprising:

an outer housing;

a mass reciprocably disposed relative to the housing;

5 a piezoelectric material; and

a bias member positioned between the mass and the piezoelectric material,

pressure fluctuations in the housing causing the mass to displace and thereby induce strain in the piezoelectric material via the bias member.

10 24. The generator according to Claim 23, wherein the pressure fluctuations are due to fluid flowing through the housing.

25. The generator according to Claim 23, further comprising a fluid conduit extending in the outer housing, the mass, bias member and piezoelectric material being externally positioned relative to the fluid conduit.

15 26. The generator according to Claim 25, wherein the mass, bias member and piezoelectric material are disposed in a chamber formed between the fluid conduit and the outer housing.

27. The generator according to Claim 25, wherein the fluid conduit is plugged, fluid flow therethrough being bypassed to a chamber formed between the outer housing and the fluid conduit.

20 28. The generator according to Claim 23, wherein a shape of a fluid conduit disposed within the outer housing induces turbulence in fluid flow through the fluid conduit.

29. The generator according to Claim 28, wherein the fluid conduit shape is helical.

30. The generator according to Claim 28, wherein the fluid conduit shape includes a recess formed on the fluid conduit.

5 31. The generator according to Claim 30, wherein the recess extends helically on the fluid conduit.

32. The generator according to Claim 28, wherein the fluid conduit shape includes a protrusion formed on the fluid conduit.

10 33. The generator according to Claim 32, wherein the protrusion extends helically on the fluid conduit.

34. The generator according to Claim 23, wherein fluid flowing through the outer housing also flows through a fluid conduit disposed within the outer housing.

15 35. The generator according to Claim 34, further comprising a flow restriction in the fluid conduit, the flow restriction forcing at least a portion of the fluid flowing through the fluid conduit to flow between the fluid conduit and the outer housing.

36. The generator according to Claim 35, wherein the flow restriction prevents fluid flow directly through the fluid conduit.

37. A method of producing power in a subterranean well, the method comprising the steps of:

interconnecting an outer housing in a tubular string;
positioning the tubular string in the subterranean well; and

5 flowing fluid through the outer housing, thereby causing a mass to displace within the housing and induce strain in a piezoelectric material via a bias member positioned between the mass and the piezoelectric material.

10 38. The method according to Claim 37, wherein the flowing fluid step further comprises flowing fluid through a fluid conduit extending in the outer housing, the mass, bias member and piezoelectric material being externally positioned relative to the fluid conduit.

15 39. The method according to Claim 38, wherein in the flowing fluid step, the mass, bias member and piezoelectric material are disposed in a chamber formed between the fluid conduit and the outer housing.

20 40. The method according to Claim 38, wherein in the flowing fluid step, the fluid conduit is plugged, fluid flow therethrough being bypassed to a chamber formed between the outer housing and the fluid conduit.

41. The method according to Claim 37, wherein in the flowing fluid step, a shape of a fluid conduit disposed within the outer housing induces turbulence in fluid flow
20 therethrough.

42. The method according to Claim 41, wherein the fluid conduit shape is helical.

43. The method according to Claim 41, wherein the fluid conduit shape includes a recess formed on the fluid conduit.

44. The method according to Claim 43, wherein the recess extends helically on the fluid conduit.

5 45. The method according to Claim 41, wherein the fluid conduit shape includes a protrusion formed on the fluid conduit.

46. The method according to Claim 45, wherein the protrusion extends helically on the fluid conduit.

10 47. The method according to Claim 37, wherein in the flowing fluid step, the fluid flowing through the outer housing also flows through a fluid conduit disposed within the outer housing.

48. The method according to Claim 47, wherein in the flowing fluid step, a flow restriction in the fluid conduit forces at least a portion of the fluid flowing through the fluid conduit to flow between the fluid conduit and the outer housing.

15 49. The method according to Claim 48, wherein the flow restriction prevents fluid flow directly through the fluid conduit.

50. An electrical power generator for use in conjunction with a subterranean well, the generator comprising:

a fluid conduit configured for flow of fluid therethrough;

5 a fluid chamber in fluid communication with the fluid conduit, the chamber vibrating in response to pressure fluctuations in the fluid conduit; and

a piezoelectric material attached to the fluid chamber, the piezoelectric material producing electricity in response to the fluid chamber vibration.

51. The generator according to Claim 50, wherein the pressure fluctuations in the fluid conduit are due to fluid flow through the fluid conduit.

52. The generator according to Claim 50, wherein the piezoelectric material is attached to a membrane bounding a portion of the fluid chamber.

53. The generator according to Claim 50, wherein the fluid chamber is formed between the fluid conduit and an outer housing outwardly circumscribing the fluid conduit.

15 54. The generator according to Claim 53, wherein the piezoelectric material is attached to the outer housing.

55. The generator according to Claim 50, wherein the piezoelectric material is attached to a piston.

20 56. The generator according to Claim 55, wherein the piston is displaceable relative to the fluid conduit to thereby adjust a volume of the fluid chamber.

57. The generator according to Claim 50, wherein the piezoelectric material is attached to the fluid conduit.

58. The generator according to Claim 50, wherein the fluid conduit is shaped so that it induces turbulence in fluid flow therethrough.

59. The generator according to Claim 50, wherein the fluid conduit is helically shaped.

60. The generator according to Claim 50, wherein the fluid conduit has a recess internally formed thereon, the recess inducing turbulence in fluid flow through the fluid conduit.

10 61. The generator according to Claim 60, wherein the recess extends generally helically on the fluid conduit.

62. A method of producing power in a subterranean well, the method comprising the steps of:

interconnecting a fluid conduit in a tubular string;

positioning the tubular string in the subterranean well;

5 flowing fluid through the fluid conduit;

vibrating a fluid chamber in fluid communication with the fluid conduit in response to the flowing fluid step; and

producing electricity from a piezoelectric material in response to the vibrating step.

10 63. The method according to Claim 62, wherein the vibrating step further comprises vibrating a membrane of the fluid chamber, the piezoelectric material being attached to the membrane.

15 64. The method according to Claim 62, wherein in the vibrating step, the fluid chamber is formed between the fluid conduit and an outer housing.

65. The method according to Claim 64, wherein in the producing electricity step, the piezoelectric material is attached to the outer housing.

20 66. The method according to Claim 62, wherein in the producing electricity step, the piezoelectric material is attached to a piston bounding a portion of the fluid chamber.

67. The method according to Claim 66, further comprising the step of displacing the piston to thereby optimize vibration of the fluid chamber in response to fluid flow through the fluid conduit.

68. The method according to Claim 62, wherein in the producing electricity step, the piezoelectric material is attached to the fluid conduit.

69. The method according to Claim 62, wherein the flowing step further comprises inducing turbulence in the fluid flowing through the fluid conduit.

5 70. The method according to Claim 69, wherein the inducing turbulence step further comprises shaping the fluid conduit in a manner increasing turbulence in the fluid flowing through the fluid conduit.

71. The method according to Claim 70, wherein the shaping step further comprises helically forming the fluid conduit.

10 72. The method according to Claim 70, wherein the shaping step further comprises forming a recess internally on the fluid conduit.

73. The method according to Claim 72, wherein the forming step further comprises forming the recess helically on the fluid conduit.

74. An electrical power generator for use in conjunction with a subterranean well, the generator comprising:

a fluid conduit having a flow passage for flow of fluid therethrough;

5 a member extending into the flow passage, the member vibrating in response to fluid flow through the fluid conduit; and

a piezoelectric material producing electricity in response to vibration of the member.

75. The generator according to Claim 74, wherein the member extends generally transversely relative to the flow passage.

10 76. The generator according to Claim 74, wherein the piezoelectric material supports the member in position relative to the fluid conduit.

77. The generator according to Claim 76, wherein the piezoelectric material encircles the member.

15 78. The generator according to Claim 76, wherein the member extends into a recess formed internally on the fluid conduit.

79. The generator according to Claim 78, wherein the piezoelectric material is disposed in the recess between the member and the fluid conduit.

20 80. The generator according to Claim 74, wherein the fluid conduit further has a protrusion extending inwardly into the flow passage, the protrusion inducing turbulence in fluid flow through the flow passage, thereby increasing vibration of the member.

81. A method of producing power in a subterranean well, the method comprising the steps of:

interconnecting in a tubular string a fluid conduit having a flow passage;

positioning the tubular string in the subterranean well;

5 flowing fluid through the flow passage;

vibrating a member extending into the flow passage in response to the flowing fluid step; and

producing electricity from a piezoelectric material in response to the member vibrating step.

10 82. The method according to Claim 81, wherein the flowing fluid step further comprises flowing fluid transversely across the member.

83. The method according to Claim 81, wherein the producing electricity step further comprises supporting the member relative to the fluid conduit utilizing the piezoelectric material.

15 84. The method according to Claim 83, wherein the supporting step further comprises encircling the member with the piezoelectric material.

85. The method according to Claim 83, wherein the supporting step further comprises positioning the piezoelectric material between the member and the fluid conduit in a recess formed internally on the fluid conduit.

20 86. The method according to Claim 81, further comprising the step of inducing turbulence in the flow passage upstream of the member, thereby increasing vibration of the member in the member vibrating step.

87. The method according to Claim 86, wherein the inducing turbulence step further comprises providing a protrusion extending inwardly into the flow passage.

2025 RELEASE UNDER E.O. 14176

88. An electrical power generator for use in conjunction with a subterranean well, the generator comprising:

a fluid conduit;

5 a member having an orifice formed therethrough, fluid flow through the fluid conduit also flowing through the orifice, and the member vibrating in response to fluid flow through the orifice; and

a piezoelectric material disposed proximate the member, the piezoelectric material producing electricity in response to vibration of the member.

10 89. The generator according to Claim 88, wherein the piezoelectric material is disposed in a recess formed internally on the fluid conduit.

90. The generator according to Claim 89, wherein a portion of the member extends into the recess.

91. The generator according to Claim 90, wherein the piezoelectric material is positioned between the portion of the member and the fluid conduit in the recess.

15 92. The generator according to Claim 88, further comprising a structure inducing turbulence in fluid flow through the fluid conduit.

93. The generator according to Claim 92, wherein the structure extends generally transversely to a flow passage formed through the fluid conduit.

94. A method of producing power in a subterranean well, the method comprising the steps of:

interconnecting in a tubular string a power generator including a member having an orifice formed therethrough;

5 positioning the tubular string in the subterranean well;

flowing fluid through the orifice;

vibrating the member in response to the flowing fluid step; and

producing electricity from a piezoelectric material in response to the member vibrating step.

10 95. The method according to Claim 94, further comprising the step of inducing turbulence in fluid flowing through the orifice.

96. The method according to Claim 95, wherein the inducing turbulence step further comprises positioning a structure in the fluid conduit upstream of the member.

15 97. The method according to Claim 96, wherein the positioning step further comprises positioning the structure so that it extends generally transversely relative to a flow passage formed through the fluid conduit.

98. An electrical power generator for use in conjunction with a subterranean well, the generator comprising:

a fluid conduit;

5 a member disposed within the fluid conduit, the member displacing within the fluid conduit in response to fluid flow through the fluid conduit;

a retainer preventing displacement of the member out of the fluid conduit; and

a piezoelectric material producing electricity in response to displacement of the member.

99. The generator according to Claim 98, wherein the piezoelectric material is disposed between the member and the fluid conduit.

100. The generator according to Claim 99, wherein the piezoelectric material supports the member within the fluid conduit.

101. The generator according to Claim 98, wherein the piezoelectric material is disposed between the retainer and the fluid conduit.

15 102. The generator according to Claim 101, wherein the piezoelectric material supports the retainer.

103. The generator according to Claim 98, wherein the member contacts the retainer in response to fluid flow through the fluid conduit, the piezoelectric material producing electricity in response to such contact.

104. A method of producing power in a subterranean well, the method comprising the steps of:

interconnecting a fluid conduit in a tubular string;

positioning the tubular string in the subterranean well;

5 flowing fluid through the fluid conduit;

displacing a member within the fluid conduit in response to the flowing fluid step; and

producing electricity from a piezoelectric material in response to the member displacing step.

10 105. The method according to Claim 104, wherein in the member displacing step, the member is prevented from displacing out of the fluid conduit by a retainer.

15 106. The method according to Claim 105, wherein the member displacing step further comprises contacting the retainer with the member, and wherein in the producing electricity step, the piezoelectric material produces electricity in response to the member contacting the retainer.

107. The method according to Claim 105, further comprising the step of supporting the retainer utilizing the piezoelectric material.

108. The method according to Claim 104, further comprising the step of supporting the member in the fluid conduit utilizing the piezoelectric material.

109. An electrical power generator for use in conjunction with a subterranean well, the generator comprising:

a fluid conduit having a flow passage formed therethrough and a cavity;

5 a membrane separating the flow passage from the cavity, the membrane flexing in response to pressure fluctuations in the flow passage; and

a piezoelectric material disposed within the cavity, the piezoelectric material producing electricity in response to the membrane flexing.

110. The generator according to Claim 109, wherein the pressure fluctuations are due to fluid flow through the flow passage.

111. The generator according to Claim 109, wherein the membrane is generally tubular.

112. The generator according to Claim 109, wherein the membrane sealingly isolates the cavity from the flow passage.

113. The generator according to Claim 112, wherein the cavity is at atmospheric pressure.

114. The generator according to Claim 109, wherein the cavity is generally annular shaped and outwardly surrounds the membrane.

115. The generator according to Claim 114, wherein the piezoelectric material is generally annular shaped and outwardly surrounds the membrane.

116. A method of producing power in a subterranean well, the method comprising the steps of:

interconnecting a fluid conduit in a tubular string;

positioning the tubular string in the subterranean well;

5 flowing fluid through a flow passage of the fluid conduit;

flexing a membrane separating the flow passage from a cavity of the fluid conduit in response to the flowing fluid step; and

producing electricity from a piezoelectric material in response to the membrane flexing step.

10 117. The method according to Claim 116, wherein in the membrane flexing step, the membrane is generally tubular.

118. The method according to Claim 116, wherein the flowing fluid step further comprises flowing fluid through the membrane.

15 119. The method according to Claim 116, further comprising the step of sealingly isolating the flow passage from the cavity utilizing the membrane.

120. The method according to Claim 116, wherein in the membrane flexing step, the cavity is at a reduced pressure relative to the flow passage.

121. The method according to Claim 120, wherein in the membrane flexing step, the cavity is at atmospheric pressure.

122. The method according to Claim 116, wherein in the membrane flexing step, the cavity outwardly surrounds the membrane.

123. The method according to Claim 116, wherein in the producing electricity step, the piezoelectric material outwardly surrounds the membrane.